The Occurrence of *Cyclops kolensis* Lilljeborg (Copepoda, Cyclopoida) in North America[1]

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Cyclops kolensis was named by Lilljeborg in 1901; in the intervening 60 odd years, it has been infrequently reported in the literature. Kozminski (1933) noted that although *C. kolensis* is one of the most widely distributed species "in our region" it had been forgotten until recent years when he and Rzoska (1930) independently mentioned it in revisions of certain groups of *Cyclops.*

Judging from the list of synonyms prepared by Lindberg (1957) the name *C. kolensis* rarely has been incorrectly applied to other species. However, the reverse has occurred rather frequently; that is, animals which are actually *C. kolensis* have been assigned to other species. Apparently the most common misidentification has been to mistake *C. kolensis* for *C. vicinus* Uljanin. Less frequently it has been confused with *C. strenuus;* for example, Kiefer (1929) included *kolensis* as a doubtful synonym of *strenuus.*

The first evidence of *C. kolensis* on the North American continent appeared in some of the collections of the Canadian Arctic Expedition of 1913–1916. Marsh (1920) recorded finding in collections made at Bernard Harbour, N.W.T., and at Cape Collinson, Alaska, a number of freshwater cyclops with a spine formula of 2,3,3,3 but which in other features agreed with the description of *C. strenuus.* Marsh assigned his Canadian and Alaskan specimens to *C. vicinus* Uljanin 1875, noting that, because *C. kolensis* Lilljeborg and *C. minutus* Lilljeborg have the same formula of spines as does *C. vicinus* on the outer margins of the terminal segments of the exopodites of the swimming legs, he could see no reason for regarding these as distinct species (Marsh, 1920:11). Marsh also regarded *C. scutifer* as a synonym of *C. strenuus* on the basis that both have a spine formula of 3,4,3,3, thus obscuring the fact that both species occur in arctic North America.

Kozminski (1936) questioned the assignment of the North American specimens to *C. vicinus,* remarking that the furcal rami of *C. scutifer* and *C. kolensis* are similar, whereas the rami of *C. vicinus* are quite different from those of *C. scutifer.* Because Marsh had made his diagnosis chiefly on the basis of the spine formula, Kozminski (1936:225) believed it quite likely that the animals in question were *C. kolensis.*

Yeatman (1944) re-examined Marsh's collections, which had been deposited in the U. S. National Museum. He noted that the Alaskan specimens differed from *C. vicinus* in proportions of the furcal rami and in the relative lengths of some of the terminal furcal setae. Yeatman further noted that the shapes of the 4th and 5th thoracic segments of Marsh's specimens differed from *C. scutifer,* in which these segments are expanded. *C. kolensis* does not have expanded thoracic segments; the thoracic segments of *C. vicinus* are strongly expanded. However, in spite of these differences Yeatman (1944:84) believed that Marsh had correctly assigned his specimens to *C. vicinus.*

Rylov (1948:198), in giving the known distribution of *C. kolensis,* considered Marsh's specimens to belong to that species.

Lindberg (1956) revived the question and proposed *Cyclops kolensis alaskaensis* as a nomen novum for the Alaskan specimens. He noted (p. 117) that neither the form of the 4th and 5th thoracic segments nor the proportions of the furca as figured by Yeatman conform to the description of *C. vicinus* Uljanin. Lindberg (1957) further contrasts *C. k. alaskaensis* with *C. k. kolensis* on the basis of the figures and discussions of Marsh and Yeatman.

Until recently the only specimens of *C. kolensis* from North America were apparently

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the few alcohol-preserved specimens and slides of dissected animals in the Marsh collections in the U. S. National Museum. Yeatman (1944) noted that the whole specimens were so thickly covered with ecto-commensal protozoans that details were difficult to observe. I also examined Marsh's material and agree that it is difficult to study. Thus the availability of new specimens is of interest. Mrs. Mildred S. Wilson, Arctic Health Research Center, Anchorage, Alaska, forwarded some collections from Saint Matthew Island, Bering Strait. These collections were made by Dr. Robert Rausch and Reggie Rausch of the same Center. Dr. J. Kalff, Department of Zoology, McGill University, Montreal, sent several vials of *Cyclops* from the vicinity of Pt. Barrow, Alaska.

COMPARISON OF *C. kolensis* WITH *C. vicinus*

Four more or less consistent differences between *C. kolensis* and *C. vicinus* appear to be in (1) the shape of the posterior corners of the 4th thoracic segment, (2) the ratio of ramus length to width, (3) the ratio of inner terminal seta of ramus to outer terminal seta, and (4) the ratio of inner terminal seta to length of ramus. Table 1 summarizes and compares these morphological features for the two species.

The antennules of both *C. vicinus* and *C. kolensis* typically have 17 segments, although Kozminski (1934) noted that specimens with 16 segments occasionally may be found. *C. kolensis* from Lake Baikal may have as many as 18 segments in the antennule (Lindberg, 1955). *C. vicinus* and *C. kolensis* share the same spine formula on the outer margins of the terminal segments of the exopods of the swimming legs —2,3,3,3. A chitinous ridge occurs on the dorsal surface of each furcal ramus.

Lilljeborg (1901) illustrated *C. kolensis* (Figs. 11 and 12) and *C. vicinus* (Figs. 16, 17, 18, and 19). The 4th thoracic segment of *C. kolensis* is but little wider than the genital segment and is figured with blunt laterally directed projections. The rami are about 5 times as long as wide; the inner terminal setae are slightly longer than the rami; the outer terminal setae are about two thirds the length of the inner. The seminal receptacle is shown as filling most of the genital segment.

The 4th thoracic segment of *C. vicinus* is shown with sharply pointed wings which are laterally and posteriorly directed. It is much

TABLE 1

MORPHOLOGICAL CHARACTERISTICS OF *Cyclops kolensis* AND *Cyclops vicinus* AS DESCRIBED IN THE LITERATURE[a]

Cyclops kolensis	*Cyclops vicinus*
Posterior corners of the fourth thoracic segment rounded or produced laterally 1, 6, 7, 11, 14, 15, 17	Posterior corners of the fourth thoracic segment produced and expanded into posteriorly directed wings 1, 2, 3, 4, 8, 10, 11, 13, 15, 16
Length of ramus 4 to 6 times the width 1, 4, 7, 11, 14, 15, 17	Length of furcal ramus usually 7 to 8 times the width 1, 2, 3, 5[c], 7, 9, 10, 11, 13, 15[c], 16[c]
Inner terminal seta of ramus less than twice the length of the external terminal seta 1, 4, 11, 14, 15, 17	Inner terminal seta of the ramus at least twice the length of the outer 1, 2, 3, 5, 7[e], 8, 9, 10, 11, 13, 15, 16
Inner terminal seta of the ramus less than the length of the ramus 1, 4, 7[d], 11, 14, 17	Inner terminal seta of the ramus exceeding or equalling the length of the ramus 1, 2, 3, 5, 10, 11, 13, 15, 16

[a] The numbered references are: 1, Borutsky 1960; 2, Dussart 1958; 3, Gurney 1933; 4, Herbst 1955; 5, Kiefer 1937; 6, Kozminski 1934; 7, Lindberg 1957; 8, Lint 1922; 9, Mann 1940; 10, Rylov 1935; 11, Rylov 1948; 12, Rzoska 1930; 13, Sars 1918; 14, Kozhov 1963; 15, Lilljeborg 1901; 16, Uljanin, from Lint 1922; 17, Mazepova 1960.

[b] Seta equalling ramus.

[c] 6 times.

[d] Internal apical seta not as long as furca in *C. kolensis alaskaensis*; internal apical seta exceeding ramus in *C. kolensis kolensis*.

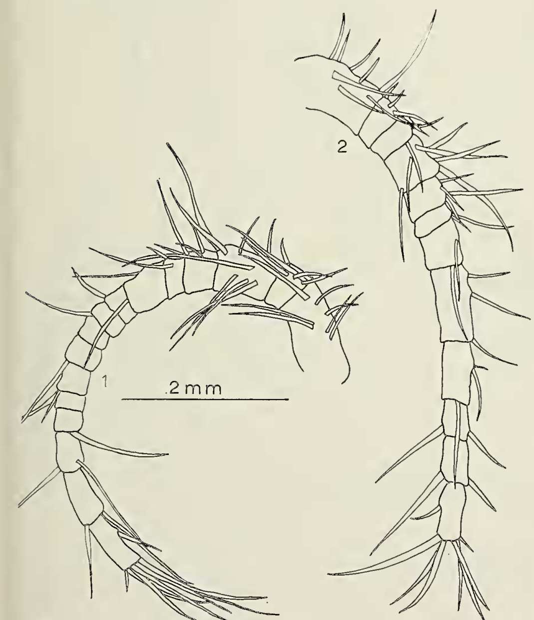
[e] Internal seta much less than twice the length of the outer in *C. vicinus kikuchi*; internal 2 or more times the length of the external in *C. vicinus vicinus*.

wider than the genital segment. The rami are about 6 times as long as wide. The inner terminal setae are a little longer than the rami and twice the length of the outer. The seminal receptacle is pictured as not filling as large a portion of the genital segment as it does in *C. kolensis.*

DESCRIPTION OF THE ALASKAN SPECIMENS

Female. The total length exclusive of the furcal setae is 1.2–1.5 mm with most ranging from 1.3–1.4 mm.

The antennules of the St. Matthew Island specimens (about 15 were available for study) are either 16- or 17-segmented (Fig. 1). Considerable variation was observed in the number of segments of the antennules of about 15 Pt. Barrow animals: a few had 17; more frequently the number was either 12 or 11. Twelve-segmented antennules resulted from the incomplete separation of segments 12, 13, and 14, and 8, 9, 10, and 11 (Fig. 2). The joint between segments 11 and 12 was distinct in all cases. Eleven-segmented antennules resulted from fusion of the segments as in the 12-segmented antennules plus the failure of segments 3 and 4 to separate completely. Gurney (1933:48) indicates that in *C. strenuus* segment 3 of the 5th copepodite antennule gives rise to segments 3 and 4 of the adult, and he suggests further that segments 8, 9, 10, and 11 of the adult arise from segment 7 of the 5th copepodite and likewise segments 12, 13, and 14 of the adult derive from segment 8 of the copepodite. Gurney states (1933:59) that female *Cyclops* (species not indicated) possess a total of 43 setae and three aesthetes on each antennule. The antennules of the Alaskan specimens, whether 17- or 12- or 11-segmented, bore this number of setae and aesthetes.



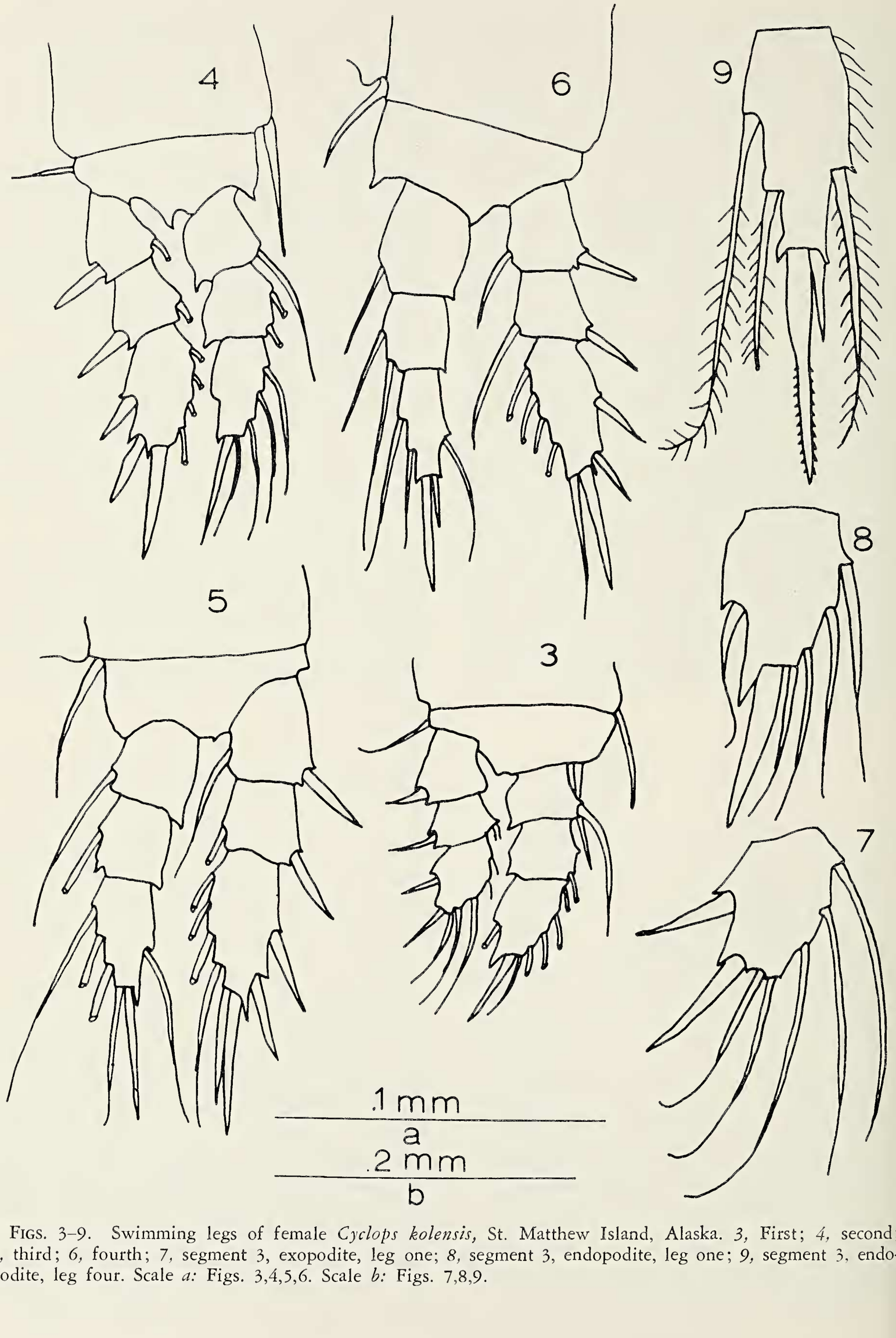
Figs. 1 and 2. Antennules of female *Cyclops kolensis. 1,* 16 segments, St. Matthew Island, Alaska; *2,* 12 segments, Pt. Barrow, Alaska.

The posterior corners of the 4th thoracic segment were either smoothly rounded or, more frequently, produced into laterally directed small processes (Figs. 10 and 11); in no instances were the corners expanded into wing-like shapes. All animals examined possessed a spine formula of 2,3,3,3 (Figs. 3–6).

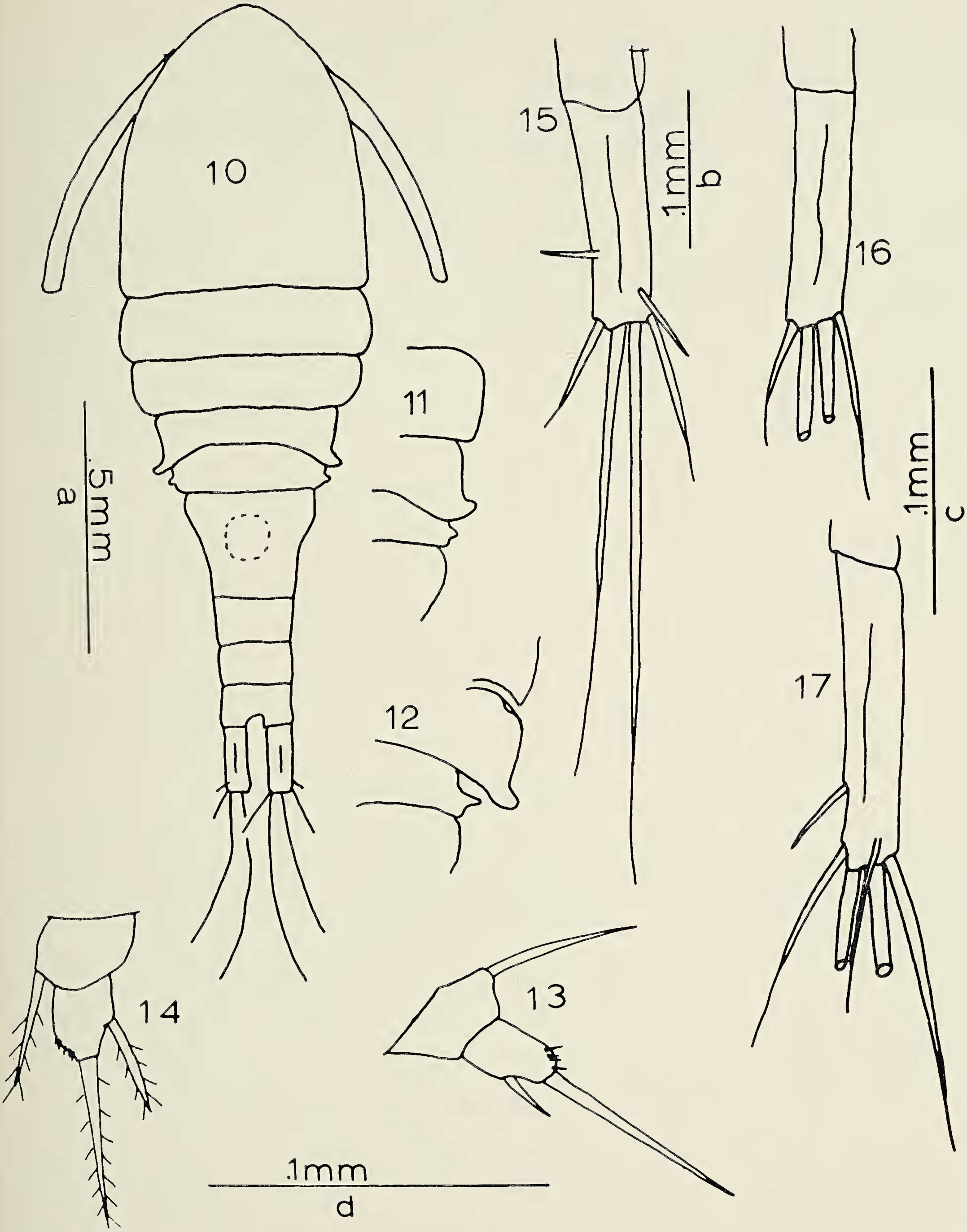
To facilitate description of individual variability found in the Alaskan specimens and to aid in comparing them with forms of *C. kolensis* described in the literature, a series of animals from each locality was measured. Table 2 summarizes measurements of morphological features which have been used traditionally in working with *C. kolensis.*

In this study of variability, ratios of body parts often have been found to be more useful than absolute measurements. Therefore Table 3 was prepared. Because the ranges of ratios are based on means ± 90% confidence limits, the ranges have a confidence limit of 81%. The effect of treating two St. Matthew Island collections separately and combined is also indicated in Tables 2, 3, and 4.

Clearly, the Pt. Barrow and St. Matthew Island populations are referable to *C. kolensis* as characterized by the morphological features used in Table 1. How similar to each other are the Alaskan populations? This question is important in helping to understand the relationships of the North American forms to those reported from other regions. Figure 18 indicates that among the Alaskan animals those from Pt. Barrow tend to be larger than those from St. Matthew 809 which are, in turn, larger than St. Matthew 814 individuals. The exceptions are lengths of inner spines of terminal



FIGS. 3–9. Swimming legs of female *Cyclops kolensis,* St. Matthew Island, Alaska. *3,* First; *4,* second; *5,* third; *6,* fourth; *7,* segment 3, exopodite, leg one; *8,* segment 3, endopodite, leg one; *9,* segment 3, endopodite, leg four. Scale *a:* Figs. 3,4,5,6. Scale *b:* Figs. 7,8,9.



FIGS. 10–14 and 15. *Cyclops kolensis,* St. Matthew Island, Alaska. *10,* Female, habitus; *11* and *12,* female, details of posterior corners of thoracic segments III, IV, V; *13,* female, leg five; *15,* female ramus; *14,* male, leg five.

FIG. 16. *Cyclops kolensis,* Canada. Female ramus.

FIG. 17. *Cyclops kolensis,* Poland. Female ramus.

TABLE 2

MEASUREMENTS OF *Cyclops kolensis*

ITEM	NUMBER OF SPECIMENS	MEAN	STANDARD DEVIATION	STANDARD ERROR	CONFIDENCE LIMIT t. 90	CONFIDENCE LIMIT AS % OF MEAN
			Point Barrow, Alaska			
Ramus length	7	163.0	12.3	4.6	8.78	5
Ramus width	7	35.3	2.5	.9	1.79	5
Inner terminal seta length	7	125.4	8.2	3.1	5.85	5
Outer terminal seta length	7	98.0	5.7	2.1	4.06	4
Segment 3 endopod leg 4 length	8	85.6	4.6	1.6	3.04	4
Segment 3 endopod leg 4 width	8	28.8	0	0	0	0
Inner terminal spine endopod leg 4 length	8	82.1	5.5	1.9	3.61	4
Outer terminal spine endopod leg 4 length	8	43.3	5.8	2.1	3.85	9
			St. Matthew Island, Alaska 809			
Ramus length	6	137.0	3.0	1.2	2.45	2
Ramus width	6	33	0	0	0	0
Inner terminal seta length	6	117	23.3	9.5	19.10	16
Outer terminal seta length	6	93	35.3	14.4	29.1	31
Segment 3 endopod leg 4 length	6	76	3.9	1.6	3.22	5
Segment 3 endopod leg 4 width	6	33	2.5	1.0	2.07	6
Inner terminal spine endopod leg 4 length	6	82	12	4.8	9.6	11
Outer terminal spine endopod leg 4 length	6	52	4.6	1.9	3.79	8
			St. Matthew Island, Alaska 814			
Ramus length	6	125	7.5	3.0	6.15	5
Ramus width	6	32	1.7	.7	1.56	5
Inner terminal seta length	6	94	16.6	6.8	13.7	15
Outer terminal seta length	6	70	8.2	3.3	6.72	10
Segment 3 endopod leg 4 length	6	63	3.0	1.2	2.46	4
Segment 3 endopod leg 4 width	6	30	3.0	1.2	2.46	8
Inner terminal spine endopod leg 4 length	6	69	10.5	4.3	8.66	14
Outer terminal spine endopod leg 4 length	6	30	3.3	1.3	2.71	9
			St. Matthew Island, Alaska 809 and 814			
Ramus length	12	129.5	8.0	2.3	5.17	4
Ramus width	12	33.0	1.1	.3	.71	2
Inner terminal seta length	12	104.0	21.3	6.17	13.75	13
Outer terminal seta length	12	81.2	15.3	4.4	9.87	12
Segment 3 endopod leg 4 length	12	69.0	7.4	2.1	4.77	7
Segment 3 endopod leg 4 width	12	31.6	3.0	.9	1.94	6
Inner terminal spine endopod leg 4 length	12	76.8	11.5	3.3	7.42	10
Outer terminal spine endopod leg 4 length	12	40.7	11.4	3.3	7.35	18

TABLE 2 (*Continued*)

ITEM	NUMBER OF SPECIMENS	MEAN	STANDARD DEVIATION	STANDARD ERROR	CONFIDENCE LIMIT t. 90	CONFIDENCE LIMIT AS % OF MEAN
			Siberia (Rylov 1948)			
Ramus length	5	156	21.8	9.8	30	20
Ramus width	5	32	2.6	1.2	4	12
Inner terminal seta length	5	113	11.4	5.1	16	14
Outer terminal seta length	5	79	6.9	3.2	10	13
Segment 3 endopod leg 4 length	3	68	7.6	2.3	7	10
Segment 3 endopod leg 4 width	3	25	2.6	1.5	4	17
Inner terminal spine endopod leg 4 length	3	71	11.5	6.6	19	27
Outer terminal spine endopod leg 4 length	3	27	3.7	2.1	6	23
			Germany (Herbst 1955)			
Ramus length	10	132.5	6.5	2.05	3.74	3.5
Ramus width	10	24.8	1.2	.4	.71	2.9
Inner terminal seta length	10	141.1	9.4	3.0	5.4	4
Outer terminal seta length	10	88.6	4.5	1.4	2.6	3
Segment 3 endopod leg 4 length	10	72.2	3.6	1.1	2.04	3
Segment 3 endopod leg 4 width	10	23.8	1.1	.4	.64	3
Inner terminal spine endopod leg 4 length	10	72.1	3.5	1.1	2.03	3
Outer terminal spine endopod leg 4 length	10	28.3	2.2	.7	1.26	4
			Alaska (Marsh's Material U.S.N.M.)			
Ramus length	8	151.6	9.3	3.1	5.9	4
Ramus width	8	31.2	1.3	1.9	3.6	12
Inner terminal seta length	7	113.3	14.6	5.5	10.7	10
Outer terminal seta length	7	80.9	6.6	2.5	4.8	6
Segment 3 endopod leg 4 length	4	72.0	3.5	1.8	4.2	6
Segment 3 endopod leg 4 width	4	22.4	2.6	1.3	3.1	14
Inner terminal spine endopod leg 4 length	4	76.0	5.5	2.8	6.6	9
Outer terminal spine endopod leg 4 length	4	33.6	4.1	2.0	4.7	14
			Poland (Kozminski's Material U.S.N.M.)			
Ramus length	3	146.1	21.3	8.2	23.9	16
Ramus width	3	27.7	1.8	1.1	3.2	12
Inner terminal seta length	3	171.7	4.9	2.8	8.4	5
Outer terminal seta length	3	109.9	8.0	4.6	13.4	12
Segment 3 endopod leg 4 length	1	79.2				
Segment 3 endopod leg 4 width	1	21.6				
Inner terminal spine endopod leg 4 length	1	70.0				
Outer terminal spine endopod leg 4 length	1	35.0				

TABLE 3

MORPHOMETRIC RATIOS OF *Cyclops kolensis* FROM DIFFERENT POPULATIONS

POPULATIONS	RAMUS LENGTH TO WIDTH	SEGMENT 3 ENDOPOD LEG 4 LENGTH : WIDTH	INNER TERMINAL SETA : OUTER TERMINAL SETA	INNER TERMINAL SETA : RAMUS	INNER TERMINAL SPINE ENDOPOD LEG 4 : OUTER TERMINAL SPINE	SEGMENT 3 ENDOPOD LEG 4 LENGTH : INNER SPINE LENGTH
Pt. Barrow, Alaska	4.6 4.1–5.1	3.0 2.9–3.1	1.2 1.2–1.4	.8 .7– .9	1.9 1.7–2.2	1.0 .96–1.1
St. Matthew Island 809	4.1 4.1–4.2	2.3 2.1–2.6	1.4 .8–2.1	.9 .7–1.2	1.6 1.3–1.9	.9 .8 –1.1
St. Matthew Island 814	3.9 3.6–4.3	2.2 1.9–2.4	1.3 1.0–1.7	.8 .6– .9	2.3 1.8–2.8	.9 .8 –1.1
St. Matthew Island combined	3.9 3.7–4.2	2.2 1.9–2.4	1.3 .9–1.6	.8 .7– .9	1.9 1.4–2.5	.9 .7 –1.6
Siberia (Rylov 1948)	5.0 3.5–6.6	2.8 2.1–3.6	1.4 1.1–1.9	.7 .5–1.0	2.6 1.6–4.3	1.0 .7 –1.4
Germany (Herbst 1955)	5.3 5.0–5.6	3.0 2.9–3.2	1.6 1.5–1.7	1.1 .9–1.3	2.6 2.4–2.7	1.0 .9 –1.1
Alaska (Marsh's material U.S.N.M.)	4.8 4.2–5.8	3.2 2.7–4.0	1.4 1.3–1.6	.7 .6– .8	2.3 1.8–2.9	.9 .8 –1.1
Poland (Kozminski's material U.S.N.M.)	5.4 4.0–6.9	3.7	1.6 1.3–1.9	1.2 1.0–1.5	2.0	1.1

segment of endopod 4 (Pt. Barrow ca. equal to St. Matthew 809) and outer spine (St. Matthew 809, the longest). Quotients of inner seta ÷ outer seta, endopod ÷ inner spine, and for the Alaskan population inner seta ÷ ramus indicate no allometry (Fig. 19, panels *C, F, D*).

Means of different measurements are compared in Table 4. The two St. Matthew populations differed at a level of .001 in lengths of furcal rami, of endopod segment 3 on leg IV, and of outer spine on the segment. The Pt. Barrow animals were most like those of St. Matthew 809 and differed greatly (five measurements at .001 level and one at .05 level) from St. Matthew 814. Comparing Pt. Barrow animals with combined St. Matthew samples showed an intermediate condition.

COMPARISON OF PRESENT SPECIMENS WITH MARSH'S MATERIAL

The U. S. National Museum loaned the Cape Collinson specimens for examination. In all, nine slides labeled by C. D. Marsh and a small vial of whole specimens in alcohol were available. Slide 4438 (Marsh's number) contained six whole females, the other slides held dissected animals. Slides 4330 and 4334 are probably *Cyclops venustoides* Coker, although labeled *C. vicinus*. Slides 4331 and 4336 are marked *C. strenuus*, but on the basis of a 2,3,3,3 spine formula are most likely *C. kolensis*. Slide 4418 labeled *C. strenuus* is *C. scutifer*. Slides 4332, 4335 and 4337 are labeled *C. vicinus*. The least distorted animals on the slides were measured (Table 2).

The alcohol-preserved specimens were considerably distorted and covered with ecto-commensal stalked protozoans. The form of the thoracic segments agrees with the descriptions of *C. kolensis* but not of *C. vicinus*.

The ratios derived from measurements in Table 2 compare favorably with ratios of other Alaskan populations (Table 3). The evidence available indicates that Marsh's specimens should be referred to *C. kolensis* Lilljeborg. Although all of the Alaskan populations do exhibit some individual characteristics as a group they differ little from one another.

COMPARISON OF ALASKAN POPULATIONS WITH OTHERS DESCRIBED IN THE LITERATURE

Rylov (1948) and Herbst (1955) measured various body parts of *C. kolensis* from Siberia and Germany (Grosser and Plöner See). Their measurements have been included in Table 2. In comparing ratios (Table 3 and Fig. 19) the Siberian and German animals do not exhibit constant patterns in relation to the other popula-

TABLE 4

Comparisons of Means of Different Measurements, *t* Values and Degrees of Freedom for Various Populations of *Cyclops kolensis*

Populations	Ramus length t	Ramus length df	Inner terminal seta length t	Inner terminal seta length df	Outer terminal seta length t	Outer terminal seta length df	Segment 3 endopod leg 4 length t	Segment 3 endopod leg 4 length df	Inner terminal spine endopod leg 4 t	Inner terminal spine endopod leg 4 df	Outer terminal spine endopod leg 4 t	Outer terminal spine endopod leg 4 df
Pt. Barrow vs Germany	6.69*	15	—3.56†	15	3.81†	15	6.98*	16	4.73*	16	7.61*	16
St. Matthew 809 vs St. Matthew 814	5.7*	10	1.97	10	1.55	10	6.48*	10	1.99	10	9.52*	10
Pt. Barrow vs Siberia	.71	10	2.21	10	5.23*	10	4.81*	9	2.26	9	4.39†	9
Pt. Barrow vs St. Matthew 809	5.00*	11	.90	11	.35	11	4.10†	12	.02	12	—3.01‡	12
Pt. Barrow vs St. Matthew 814	6.58*	11	4.44*	11	6.90*	11	10.43*	12	3.04‡	12	5.01*	12
Combined St. Matthew vs Pt. Barrow	—7.22*	17	—2.52‡	17	—2.76‡	17	—5.64*	18	—1.21	18	—.59	18
St. Matthew 809 vs Germany	1.57*	14	—2.95†	14	.42	14	2.00	14	2.50‡	14	13.67*	14
St. Matthew 814 vs Germany	—2.23*	14	—7.32*	14	5.92*	14	5.26*	14	—1.25		1.25	14
Combined St. Matthew vs Germany	—.95	20	—5.11*	20	—1.08	20	—1.25	20	1.24	20	3.37†	20

* Significant at .001 level.
† Significant at .01 level.
‡ Significant at .05 level.

tions, although there is a tendency Germany > Siberia > St. Matthew in regard to lengths of outer setae, endopods, and inner spines. The German animals had particularly short furcal rami and long inner terminal setae. The German population has a quotient > 1 for inner seta ÷ ramus (panel *D,* Fig. 19) suggesting that the lengths of these structures do indeed differ from those of the other populations. There are a number of indications that the Siberian *C. kolensis* is similar to the Pt. Barrow specimens and to a lesser extent to the St. Matthew forms (Table 3 and 4, Fig. 18).

To further assess the variation shown by the five populations, six measurements were subjected to one-way analysis of variance. The results (Table 5) show that two values (lengths of furcal rami and outer spine) are significantly different at the .01 level and that the endopod lengths differ significantly at the .05 level. Inspection of Figure 18 suggests that much of the variation in furcal length may be due to the German animals. Analyzing furcal length after omitting the German specimens resulted in an $F = 4.63$, not significant at the .05 level. Likewise if the St. Matthew 809 animals are omitted, the F value for the outer spine length is not significant at the .05 level.

Along with the specimens from the Marsh collections, the U. S. National Museum also loaned three specimens of *C. kolensis* from Lake Wigry, Poland, identified by Kozminski. Characteristics of the terminal seta, endopod, and rami of these animals are closer to those of the German specimens than they are to the Alaskan animals (Tables 3 and 4). The length of the abdominal segments (post genital) is 121% of the furcal length.

In attempting to summarize the morphological variation shown by these populations, the German animals appear to possess long inner setae and short furcal rami, resulting in only the inner

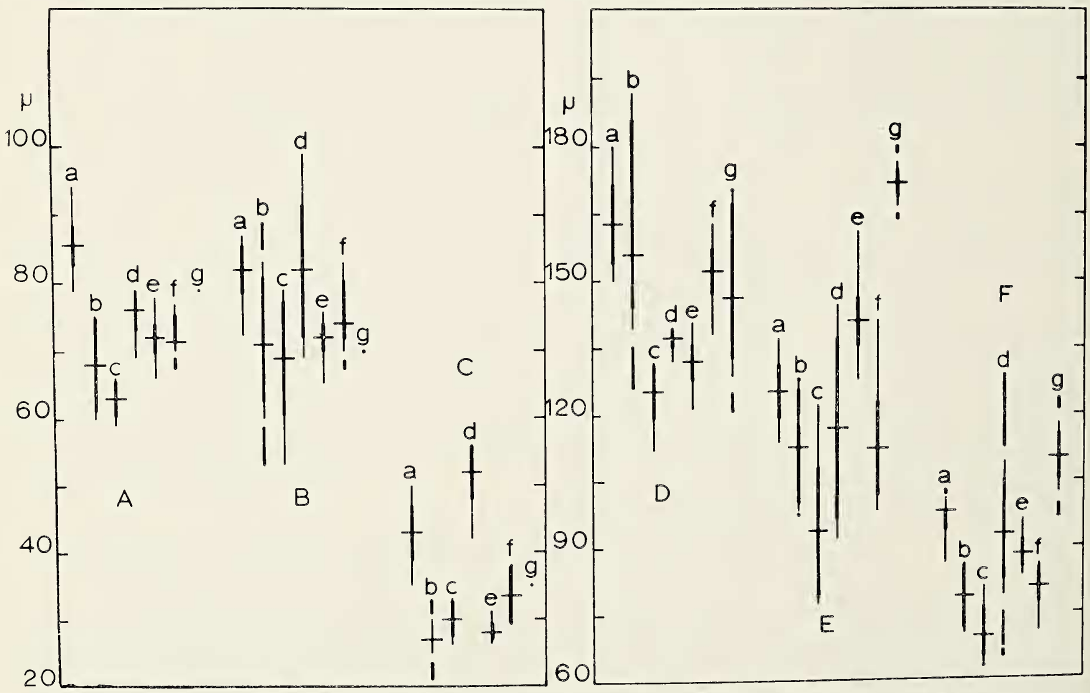


FIG. 18. Comparison of measurements of *Cyclops kolensis* from various populations. *A,* Length of segment 3, endopodite, leg four; *B,* length of inner terminal spine of segment 3, endopodite leg four; *C,* length of outer terminal spine of segment 3, endopodite, leg four; *D,* length of furcal ramus; *E,* length of inner terminal seta of ramus; *F,* length of outer terminal seta of ramus. Values in microns; thin vertical line is the range, heavy vertical line is the 90% confidence limit and horizontal bar is the mean.

Populations: *a,* Pt. Barrow, Alaska; *b,* Siberia (Rylov 1948); *c,* St. Matthew Island, Alaska (coll. 814); *d,* St. Matthew Island, Alaska (coll. 809); *e,* Grosser Plöner See (Herbst 1955); *f,* Canada (Marsh collections, U. S. National Museum); *g,* Lake Wigry, Poland (Kozminski collections U. S. National Museum).

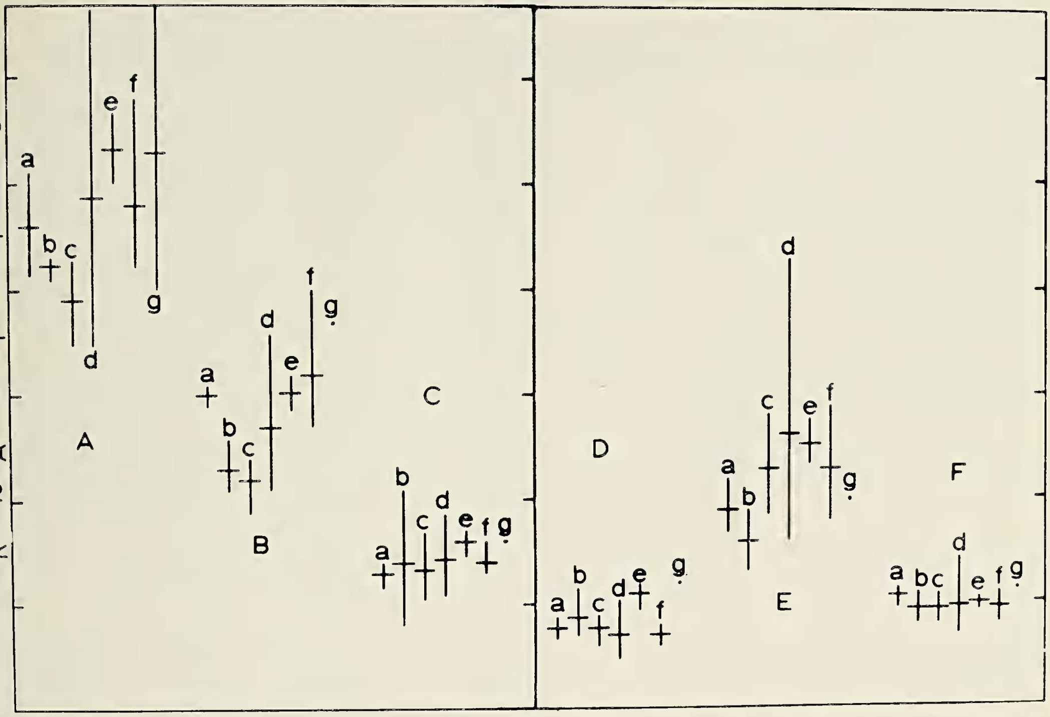


FIG. 19. Comparison of ratios of measurements of *Cyclops kolensis* from various populations. *A*, Length of furcal ramus/ width of ramus; *B*, length of segment 3, endopodite, leg four/ width of same; *C*, length of inner terminal seta of ramus/ length of outer seta of ramus; *D*, length of inner terminal seta of ramus/ length of ramus; *E*, length of inner terminal spine, endopodite, leg four/ outer terminal spine, endopodite, leg four; *F*, length of segment 3, endopodite, leg four/ inner terminal spine same appendage.
Populations: a–g as in Fig. 18.

seta to ramus length quotient exceeding unity.

Lindberg (1955) gives ratios of various body parts of *C. kolensis* from Lake Baikal and from a pond at Aneboda, Sweden. Four animals represent each locality. Means of some ratios from these populations are compared with each other and with those of animals from the Grosser Plöner See (Table 6). The Swedish and German forms differ most widely from each other. The Baikal and Swedish forms show the greatest similarity, which, in view of the great environmental differences, is unexpected.

Values of the ratios from Table 6 were subjected to analyses of variance (Table 7). Only two ratios had significant F values. These were length of outer medial terminal seta as percent of the length of the inner medial seta and the length of the inner medial seta as percent of ramus length.

Lengths of the medial furcal setae were not measured in the Alaskan specimens; however, using available measurements it is possible to make further comparisons among the present samples of *C. kolensis* and those recorded in the literature (Table 8). If the mean values only are considered, the German, Polish, Swedish, and Baikalense animals tend to have inner seta exceeding the ramus length and also to have long inner furcal seta as compared with the outer furcal seta. But the ranges overlap very broadly.

Mazepova (1961) studied *C. kolensis* from different habitats and found that it was morphologically homogeneous over its range with the exception of some bodies of water in Siberia. The northern form she considered to be *C. kolensis alaskaensis* Lindberg. She gave quotients of length of the last three abdominal segments: length of rami; Siberian animals were the only ones in which this value was over 100%, with a range between 100 and 150%. Two females from Pt. Barrow were checked for this quotient, which varied from 174 to 177%. Mazepova

TABLE 5

SUMMARY OF ONE FACTOR ANALYSIS OF VARIANCE OF MEASUREMENTS OF *Cyclops kolensis*, SAME POPULATION AS IN TABLE 4

ITEM	SOURCE	SUM OF SQUARES	DEGREES FREEDOM	MEAN SQUARE	F VALUE
Length of segment 3 endopod leg 4	Main effect	1921	4	72.58	3.925**
	Deviation	513	28	18.49	
	Total	2434	32		
Length outer spine endopod leg 4	Main effect	2527	4	103.45	6.239*
	Deviation	464	28	16.58	
	Total	2991	32		
Length inner spine endopod leg 4	Main effect	1053	4	39.85	.637
	Deviation	1635	28	62.50	
	Total	2688	32		
Length ramus	Main effect	8716	4	328.07	2.75**
	Deviation	3445	29	119.28	
	Total	12161	33		
Length outer terminal seta	Main effect	3197	4	127.63	2.429
	Deviation	1528	29	52.54	
	Total	4725	33		
Length inner terminal seta	Main effect	9227	4	318.45	1.598
	Deviation	5777	29	199.22	
	Total	15004	33		

* Significant at .01 level.
** Significant at .05 level.

TABLE 6

RATIOS OF MEAN MEASUREMENTS OF *Cyclops kolensis* FROM THREE LOCALITIES*

ITEM	ANEBODA, SWEDEN VS LAKE BAIKAL	ANEBODA, SWEDEN VS GROSSER PLÖNER SEE, GERMANY	LAKE BAIKAL VS GROSSER PLÖNER SEE, GERMANY
Length outer seta as % length ramus	2.24**	2.04**	.598
Length inner seta as % length ramus	1.44	6.61**	2.34**
Insert. lateral seta % length ramus	.578	0	—.142
Length med. inner seta % length ramus	.87	18.45**	—4.38
Width furca as % length ramus	1.26	3.09**	.205
Length inner seta as % outer	—.353	3.29**	3.73**
Length inner med. seta as % inner seta	—.33	4.37**	2.46**
Length outer med. seta as % inner med.	.236	—1.61	—6.88**

* Data from Lindberg 1957.
** Significant at .05 level.

(1961) further noted that the 4th and 5th thoracic segments of the Siberian animals were relatively much wider than those of other *C. kolensis* examined.

ECOLOGY

Rzoska (1932) indicated that biological characteristics and ecological differentiation as well as morphological features should be of help in working out the systematics of the Cyclopidae. Unfortunately, there does not appear to be as much information on the ecology of *C. kolensis* and *C. vicinus* as on their morphology.

Apparently, *C. kolensis* is generally a cold water species. Kozminski (1933) reported that in Lake Wigry, Poland, *C. kolensis* is a dicyclic species with the maximum population occurring

TABLE 7

Summary of 1 Factor Analysis of Variance of *Cyclops kolensis* from Grosser Plöner See, Aneboda, and Lake Baikal

ITEM	SOURCE	SUM OF SQUARES	DEGREES FREEDOM	MEAN SQUARES	F VALUE
Inner med. seta as % inner seta	Main effect	5,068	2	568.5	.855
	Deviation	10,966	15	664.53	
	Total	16,034			
Outer med. seta as % inner med. seta	Main effect	259	2	36.87	4.691
	Deviation	264.39	15	7.86	
	Total	523.39			
Length to insertion lateral seta % of furcal length	Main effect	3.71	2	.135	.474
	Deviation	40.13	15	2.85	
	Total	43.84			
Length of inner medial seta as % furcal length	Main effect	28,374	2	2669.5	4.942
	Deviation	8,101	15	540.2	
	Total	36,375			
Width of furca as % length	Main effect	7.36	2	.80	.777
	Deviation	16.99	15	1.03	
	Total	24.35			
Inner seta as % of outer seta	Main effect	1136	2	149	1.502
	Deviation	1404	15	99.2	
	Total	2540			
Inner seta as % ramus	Main effect	1107	2	115.38	2.717
	Deviation	2766	15	42.47	
	Total	3873			
Outer seta as % ramus	Main effect	74,479	2	14.36	.666
	Deviation	308	15	21.57	
	Total	74,787			

under the ice in February and March; a smaller population peak occurred in early summer. Later, Kozminski (1936) reported that *C. kolensis* appeared to thrive best in the eutrophic bays of Lake Wigry and in other eutrophic lakes of the region. In the open oligotrophic areas of Lake Wigry it occurred sparingly and seemed to avoid small dystrophic ponds. He also found that the species congregated in almost oxygen-free water near the bottom of Lake Wigry in February and March.

Herbst (1955) reported *C. kolensis* to be monocyclic with maximum numbers in March and April in Grosser Plöner See. Kozhov (1963) states that in Lake Baikal it occurs abundantly throughout the year in large bays and gulfs that are cooled by waters from the open lake. It occurs only during cold seasons in well sheltered bays which at other times apparently become too warm for it; however, he further states that in years when the water masses of the open lake become warmer than usual, *C. kolensis* spreads in increased numbers through all the open waters. Judging from the temperature data given by Kozhov the upper limit for the species is about 18°–20° C, and in Lake Baikal the optimum may be about 12°–14° C. Kozminski (1936) noted that Lilljeborg also recorded taking it in a shallow, relatively warm upland lake in July.

C. vicinus is reported to be a pond-dwelling species (Kozminski, 1934). Kiefer (1937) found sexually mature males and females in a small Manchurian lake in August. Rylov (1935) stated that *C. vicinus* occurs in the plankton of lakes and in small ponds. Gurney (1933) noted that in Britain the species is found in the plankton of "lakes and in small duck ponds" and seemed to be confined to eutrophic waters. Kozhov (1963) reported *C.*

TABLE 8

LENGTH OF OUTER SETA AS A PERCENT OF RAMUS IN VARIOUS POPULATIONS OF *Cyclops kolensis*

POPULATION	LENGTH OF OUTER SETA AS % OF RAMUS	LENGTH OF INNER SETA AS % OF RAMUS	WIDTH OF RAMUS AS % OF LENGTH	INNER SETA AS % OF OUTER SETA
Siberia	37.1–70.6 50.6	52.2–102.5 72.4	15.05–28.6 20.5	109–187 143
Pt. Barrow	54.8–66.2 60.2	69.6–85.0 77.0	19.5–24.1 21.6	117–139 127
St. Matthew 809	45.7–83.3 67.7	70.3–101.2 85.5	24.1	88–213 126
St. Matthew 814	48.2–63.6 56.0	61.2–90.7 75.2	23.9–28.3 25.6	105–170 134
St. Matthew combined	52.8–73.1 62.7	67.0–94.6 80.3	24.0–27.1 25.5	99–165 128
Grosser Plöner See	63.1–70.7 66.7	99.6–113.7 106.6	17.7–19.8 18.7	148–170 159
Baikal	59.4–71.0 65.2	99.3–130.7 115	17.2–20.8 19.0	159–197 178
Aneboda	67.1–77.1 72.4 60.6–71.5 65.1 58 8–67.3 65.3	118–134 126 107–130 115 103–119 113	18.8–21.8 20.3 19.0–34.0 25.2 18.0–22.0 19.8	167–181 174 156–195 177 162–180 173
Poland	72.7	118	16.5–24.3 20.4	133–193 163
Poland slides from USNM	56.6–100.3 75.3	96–149 118	14.4–25.3 18.9	133–187 161
Marsh's	46–59 53.4	63.9–85.0 74.7	17.2–24.3 20.6	123–156 140

vicinus in the warmer shallower portions of Lake Baikal where it and *C. kolensis* may at times occur together. Herbst (1955) also reported the co-occurrence of the two species in Grosser Plöner See, although *C. vicinus* was apparently less abundant and reached a peak of population at a different time than did *C. kolensis.*

DISTRIBUTION

If Kozminski (1936) was correct in believing that Olofsson (1918) had specimens of *C. kolensis* from Spitzbergen, then it is known to occur in ponds there, in the New Siberian Islands, and in Alaska. Kozhov (1963) summarized records of the species in the Yeniesi and Angara drainages. Mazepova (1961) presented a map showing localities where it has been found. One belt of records runs from southern Sweden through Poland and Germany to Lake Baikal; a second belt follows the Arctic coast of Eurasia to Alaska.

Currently three subspecies of *C. kolensis* are recognized. *C. k. kolensis, C. k. baikalensis,* and *C. k. alaskaensis. C. k. baikalensis* was described as a new species by Vasilyeva (1950). Later Lindberg (1955) and Mazepova (1960) concluded that the form in Lake Baikal was not distinguishable from *C. kolensis.* Kozhov (1963) recognized *C. baikalensis* as an ecological subspecies. Lindberg recognized *C. k. alaskaensis* on morphological grounds and Mazepova (1961) concurred.

DISCUSSION AND CONCLUSIONS

The presence of *Cyclops kolensis* Lilljeborg on the North American continent is established by the examination of new material. It seems unwise in our present state of knowledge to designate subspecies by formal trinomials. It is possible, by measuring enough morphological characteristics and selecting among them, to find at least one feature in which the animals of each lake differ from all others. Extended to the absurd conclusion each lake contains its own subspecies.

The effect of environment on the morphology of *C. kolensis* is not clear from the evidence. Environmental factors, such as temperature, turbulence, and food, are believed to affect the morphology of some species of cyclopoid copepods. How true this may be for *C. kolensis* cannot now be told. Animals living in ponds in Sweden exhibit several features in common with those dwelling in Lake Baikal; others living in nearby ponds on St. Matthew Island show features in common and also differences.

Species of supposed immediate common ancestry could be expected to share many features in common. Thus, if minor differences could be consistently associated with forms exhibiting reproductive isolation they would be sibling species—not subspecies. We cannot say whether or not different populations of *C. kolensis* are reproductively isolated. Geographic separation and the fact that local differences are discernible would suggest that gene flow at least is restricted. The possibility of sibling species is not ruled out by present evidence. What does appear to be ruled out is the desirability of using subspecific names.

ZUSAMMENFASSUNG

Cyclops kolensis Lilljeborg wurde während neuer Untersuchungen auf der Insel St. Matthew und bei Point Barrow, Alaska gefunden. Überprüfung der Marsh Sammlungen (U. S. National Museum) brachte zusätzliche Species vom arktischen Kanada an's Licht.

Acht anatomische Eigenschaften wurden in drei Populationen von Tieren Alaska's gemessen, die sich als nützlich erwiesen, Species von *Cyclops* zu unterscheiden. Masse und Verhältnisse zwischen Massen von *C. kolensis* von Alaska und von Schweden, Deutschland, Polen, Baikal See und andern sibirischen Seen wurden statistisch verglichen. Masse von Tieren ausserhalb Alaska's waren der Literatur entnommen worden.

Die statistischen Vergleiche fuhrten zu keinem klaren Ergebnis. Die meisten Populationen unterschieden sich mit Signifikanz zumindest in einer Eigenschaft von allen andern; jedoch unterschied sich nicht eine Population in allen Eigenschaften von allen andern.

Ehe nicht mehr über die Morphologie, Verteilung und Ökologie von *Cyclops kolensis* bekannt ist, erscheint es unweise, Subspecies-Namen zu verleihen.

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